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A DETERMINATION OF THE PRINCIPLES AND EXPERIMENTS OF PHYSICAL AND BIOLOGICAL SCIENCE FOUND IN FOUR NINTH-GRADE TEXTBOOKS OF GENERAL SCIENCE

by

Manning Stewart Case

submitted in partial fulfillment of the
requirements for the degree of
Master of Education
July, 1947

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Acknowledgement is made at this time to Professor Vaden W. Miles, the director of this thesis, without whose untiring efforts, expert advice and opinion this investigation would have been impossible. The author wishes to pay tribute to the many investigators in the field of science education upon whose findings this investigation is based. The writer also wishes to extend the sincerest appreciation to the members of the Seminar in Science Education, Boston University, 1946-47 for their assistance in establishing the criteria used in this investigation. The author further wishes to extend appreciation and gratitude to his wife, Eleanor H. Case, for her constant encouragement and gracious assistance in making this investigation possible. Finally, the investigator is highly indebted to (Mrs.) Maxine S. Miles and to the director of this thesis for their part in the validation of (1) the statements of the minor principles, (2) the assignment of these minor principles to major principles, and (3) of the assignments of the experiments to the principles.

TABLE OF CONTENTS

		Page
	List of Tables	vi
CHAPTER		
I	SURVEY OF RELATED LITERATURE	1
	Introduction	1
	Survey of Important Research Studies Pertaining to the Determination of Principles as Objectives of Science Teaching	5
	Survey of Important Research Studies Pertaining to the Effectiveness of Teaching Principles in Terms of the Retention of Learning	13
	Survey of Important Research Studies Pertaining to the Determination of Experiments to be Used for Developing Principles of Science	16
	Summary of Research Studies	16
	The Problem of This Investigation	18
	Statement of the Problem	18
	Scope and Limitations of This Investigation	19
II	RESEARCH	20
	Statement of the Problem	20
	Techniques Employed	20
	Criteria for the Selection of Textbooks for Analysis	20
	Criteria for the Selection of Principles from Textbooks	21
	Method of Analysis of Textbooks for Principles	23
	Index of Reliability for the Selection of Principles from Textbooks	25
	Criteria for the Statement of a Principle for Comprehension at the Ninth-grade Level	26
	Validation of the Statements of Principles for Comprehension at the Ninth-grade Level and of the Assignment of Those Principles to Major Principles of Physical Science and/or Biological Science	27

TABLE OF CONTENTS

Page

List of Tables iii

CHAPTER

I 1

II 6

III 12

IV 18

V 24

VI 30

VII 36

VIII 42

IX 48

X 54

XI 60

XII 66

XIII 72

XIV 78

XV 84

XVI 90

XVII 96

XVIII 102

XIX 108

XX 114

XXI 120

XXII 126

XXIII 132

XXIV 138

XXV 144

XXVI 150

XXVII 156

XXVIII 162

XXIX 168

XXX 174

XXXI 180

XXXII 186

XXXIII 192

XXXIV 198

XXXV 204

XXXVI 210

XXXVII 216

XXXVIII 222

XXXIX 228

XL 234

XLI 240

XLII 246

XLIII 252

XLIV 258

XLV 264

XLVI 270

XLVII 276

XLVIII 282

XLIX 288

L 294

LI 300

LII 306

LIII 312

LIV 318

LV 324

LVI 330

LVII 336

LVIII 342

LIX 348

LX 354

LXI 360

LXII 366

LXIII 372

LXIV 378

LXV 384

LXVI 390

LXVII 396

LXVIII 402

LXIX 408

LXX 414

LXXI 420

LXXII 426

LXXIII 432

LXXIV 438

LXXV 444

LXXVI 450

LXXVII 456

LXXVIII 462

LXXIX 468

LXXX 474

LXXXI 480

LXXXII 486

LXXXIII 492

LXXXIV 498

LXXXV 504

LXXXVI 510

LXXXVII 516

LXXXVIII 522

LXXXIX 528

XC 534

XCI 540

XCII 546

XCIII 552

XCIV 558

XCV 564

XCVI 570

XCVII 576

XCVIII 582

XCIX 588

C 594

CI 600

CII 606

CIII 612

CIV 618

CV 624

CVI 630

CVII 636

CVIII 642

CIX 648

CX 654

CXI 660

CXII 666

CXIII 672

CXIV 678

CXV 684

CXVI 690

CXVII 696

CXVIII 702

CXIX 708

CXX 714

CXXI 720

CXXII 726

CXXIII 732

CXXIV 738

CXXV 744

CXXVI 750

CXXVII 756

CXXVIII 762

CXXIX 768

CXXX 774

CXXXI 780

CXXXII 786

CXXXIII 792

CXXXIV 798

CXXXV 804

CXXXVI 810

CXXXVII 816

CXXXVIII 822

CXXXIX 828

CXL 834

CXLI 840

CXLII 846

CXLIII 852

CXLIV 858

CXLV 864

CXLVI 870

CXLVII 876

CXLVIII 882

CXLIX 888

CL 894

CLI 900

CLII 906

CLIII 912

CLIV 918

CLV 924

CLVI 930

CLVII 936

CLVIII 942

CLIX 948

CLX 954

CLXI 960

CLXII 966

CLXIII 972

CLXIV 978

CLXV 984

CLXVI 990

CLXVII 996

CLXVIII 1002

CLXIX 1008

CLXX 1014

CLXXI 1020

CLXXII 1026

CLXXIII 1032

CLXXIV 1038

CLXXV 1044

CLXXVI 1050

CLXXVII 1056

CLXXVIII 1062

CLXXIX 1068

CLXXX 1074

CLXXXI 1080

CLXXXII 1086

CLXXXIII 1092

CLXXXIV 1098

CLXXXV 1104

CLXXXVI 1110

CLXXXVII 1116

CLXXXVIII 1122

CLXXXIX 1128

CXC 1134

CXCI 1140

CXCII 1146

CXCIII 1152

CXCIV 1158

CXCV 1164

CXCVI 1170

CXCVII 1176

CXCVIII 1182

CXCIX 1188

CC 1194

CCI 1200

CCII 1206

CCIII 1212

CCIV 1218

CCV 1224

CCVI 1230

CCVII 1236

CCVIII 1242

CCIX 1248

CCX 1254

CCXI 1260

CCXII 1266

CCXIII 1272

CCXIV 1278

CCXV 1284

CCXVI 1290

CCXVII 1296

CCXVIII 1302

CCXIX 1308

CCXX 1314

CCXXI 1320

CCXXII 1326

CCXXIII 1332

CCXXIV 1338

CCXXV 1344

CCXXVI 1350

CCXXVII 1356

CCXXVIII 1362

CCXXIX 1368

CCXXX 1374

CCXXXI 1380

CCXXXII 1386

CCXXXIII 1392

CCXXXIV 1398

CCXXXV 1404

CCXXXVI 1410

CCXXXVII 1416

CCXXXVIII 1422

CCXXXIX 1428

CCXL 1434

CCXLI 1440

CCXLII 1446

CCXLIII 1452

CCXLIV 1458

CCXLV 1464

CCXLVI 1470

CCXLVII 1476

CCXLVIII 1482

CCXLIX 1488

CCL 1494

CCLI 1500

CCLII 1506

CCLIII 1512

CCLIV 1518

CCLV 1524

CCLVI 1530

CCLVII 1536

CCLVIII 1542

CCLIX 1548

CCLX 1554

CCLXI 1560

CCLXII 1566

CCLXIII 1572

CCLXIV 1578

CCLXV 1584

CCLXVI 1590

CCLXVII 1596

CCLXVIII 1602

CCLXIX 1608

CCLXX 1614

CCLXXI 1620

CCLXXII 1626

CCLXXIII 1632

CCLXXIV 1638

CCLXXV 1644

CCLXXVI 1650

CCLXXVII 1656

CCLXXVIII 1662

CCLXXIX 1668

CCLXXX 1674

CCLXXXI 1680

CCLXXXII 1686

CCLXXXIII 1692

CCLXXXIV 1698

CCLXXXV 1704

CCLXXXVI 1710

CCLXXXVII 1716

CCLXXXVIII 1722

CCLXXXIX 1728

CCXC 1734

CCXCI 1740

CCXCII 1746

CCXCIII 1752

CCXCIV 1758

CCXCV 1764

CCXCVI 1770

CCXCVII 1776

CCXCVIII 1782

CCXCIX 1788

CCC 1794

CCCI 1800

CCCII 1806

CCCIII 1812

CCCIV 1818

CCCV 1824

CCCVI 1830

CCCVII 1836

CCCVIII 1842

CCCIX 1848

CCCX 1854

CCCXI 1860

CCCXII 1866

CCCXIII 1872

CCCXIV 1878

CCCXV 1884

CCCXVI 1890

CCCXVII 1896

CCCXVIII 1902

CCCXIX 1908

CCCXX 1914

CCCXXI 1920

CCCXXII 1926

CCCXXIII 1932

CCCXXIV 1938

CCCXXV 1944

CCCXXVI 1950

CCCXXVII 1956

CCCXXVIII 1962

CCCXXIX 1968

CCCXXX 1974

CCCXXXI 1980

CCCXXXII 1986

CCCXXXIII 1992

CCCXXXIV 1998

CCCXXXV 2004

CCCXXXVI 2010

CCCXXXVII 2016

CCCXXXVIII 2022

CCCXXXIX 2028

CCCXL 2034

CCCXLI 2040

CCCXLII 2046

CCCXLIII 2052

CCCXLIV 2058

CCCXLV 2064

CCCXLVI 2070

CCCXLVII 2076

CCCXLVIII 2082

CCCXLIX 2088

CCCL 2094

CCCLI 2100

CCCLII 2106

CCCLIII 2112

CCCLIV 2118

CCCLV 2124

CCCLVI 2130

CCCLVII 2136

CCCLVIII 2142

CCCLIX 2148

CCCLX 2154

CCCLXI 2160

CCCLXII 2166

CCCLXIII 2172

CCCLXIV 2178

CCCLXV 2184

CCCLXVI 2190

CCCLXVII 2196

CCCLXVIII 2202

CCCLXIX 2208

CCCLXX 2214

CCCLXXI 2220

CCCLXXII 2226

CCCLXXIII 2232

CCCLXXIV 2238

CCCLXXV 2244

CCCLXXVI 2250

CCCLXXVII 2256

CCCLXXVIII 2262

CCCLXXIX 2268

CCCLXXX 2274

CCCLXXXI 2280

CCCLXXXII 2286

CCCLXXXIII 2292

CCCLXXXIV 2298

CCCLXXXV 2304

CCCLXXXVI 2310

CCCLXXXVII 2316

CCCLXXXVIII 2322

CCCLXXXIX 2328

CCCXC 2334

CCCXCI 2340

CCCXCII 2346

CCCXCIII 2352

CCCXCIV 2358

CCCXCV 2364

CCCXCVI 2370

CCCXCVII 2376

CCCXCVIII 2382

CCCXCIX 2388

CD 2394

CDI 2400

CDII 2406

CDIII 2412

CDIV 2418

CDV 2424

CDVI 2430

CDVII 2436

CDVIII 2442

CDIX 2448

CDX 2454

CDXI 2460

CDXII 2466

CDXIII 2472

CDXIV 2478

CDXV 2484

CDXVI 2490

CDXVII 2496

CDXVIII 2502

CDXIX 2508

CDXX 2514

CDXXI 2520

CDXXII 2526

CDXXIII 2532

CDXXIV 2538

CDXXV 2544

CDXXVI 2550

CDXXVII 2556

CDXXVIII 2562

CDXXIX 2568

CDXXX 2574

CDXXXI 2580

CDXXXII 2586

CDXXXIII 2592

CDXXXIV 2598

CDXXXV 2604

CDXXXVI 2610

CDXXXVII 2616

CDXXXVIII 2622

CDXXXIX 2628

CDXL 2634

CDXLI 2640

CDXLII 2646

CDXLIII 2652

CDXLIV 2658

CDXLV 2664

CDXLVI 2670

CDXLVII 2676

CDXLVIII 2682

CDXLIX 2688

CDL 2694

CDLI 2700

CDLII 2706

CDLIII 2712

CDLIV 2718

CDLV 2724

CDLVI 2730

CDLVII 2736

CDLVIII 2742

CDLIX 2748

CDLX 2754

CDLXI 2760

CDLXII 2766

CDLXIII 2772

CDLXIV 2778

CDLXV 2784

CDLXVI 2790

CDLXVII 2796

CDLXVIII 2802

CDLXIX 2808

CDLXX 2814

CDLXXI 2820

CDLXXII 2826

CDLXXIII 2832

CDLXXIV 2838

CDLXXV 2844

CDLXXVI 2850

CDLXXVII 2856

CDLXXVIII 2862

CDLXXIX 2868

CDLXXX 2874

CDLXXXI 2880

CDLXXXII 2886

CDLXXXIII 2892

CDLXXXIV 2898

CDLXXXV 2904

CDLXXXVI 2910

CDLXXXVII 2916

CDLXXXVIII 2922

CDLXXXIX 2928

CDXC 2934

CDXCI 2940

CDXCII 2946

CDXCIII 2952

CDXCIV 2958

CDXCV 2964

CDXCVI 2970

CDXCVII 2976

CDXCVIII 2982

CDXCIX 2988

D 2994

TABLE OF CONTENTS (CONCLUDED)

CHAPTER		Page
III	RESEARCH	58
	Statement of the Problem	58
	Techniques Employed	58
	Criteria for the Selection of Experiments from Textbooks	58
	Method of Analysis of Textbooks for Experiments	59
	Index of Reliability for the Selection of Experiments from Textbooks	59
	Assignment of Experiments to Principles Comprehensible at the Ninth-grade Level	60
	Validation of the Statements of the Experiments and of the Assignments of the Experiments to Principles	61
IV	SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	80
	Restatement of the Problem	80
	Summary of the Techniques Employed	80
	Summary of the Findings	83
	Conclusions	83
	Recommendations	83
BIBLIOGRAPHY		85
APPENDIX		88

LIST OF TABLES

TABLE		Page
I	MAJOR AND MINOR PRINCIPLES OF SCIENCE FOUND IN FOUR NINTH-GRADE TEXTBOOKS OF GENERAL SCIENCE.....	30
II	EXPERIMENTS THAT CAN BE USED IN DEVELOPING UNDERSTANDINGS OF THE PRINCIPLES OF PHYSICAL AND/OR BIOLOGICAL SCIENCE FOUND IN FOUR NINTH-GRADE TEXTBOOKS OF GENERAL SCIENCE.....	63

CHAPTER I

SURVEY OF RELATED LITERATURE

Introduction

In accordance with the recent trend to make education more meaningful to children, the course of study in general science at the junior-high-school level of general education has, in many cases, been built around the basic needs of the pupils. In the past twenty years there has been a definite swing among educators away from teaching factual matter as an end in itself, and toward the teaching of those scientific principles which are most useful in solving problems which arise in life situations.

The Committee for the Junior High School Curriculum set up by the Department of Superintendence of the National Education Association published in its Fifth Yearbook[1] the opinion that a knowledge of science, to be of the greatest service to mankind, should be in the form of principles and laws. It was further emphasized that a course of study in science for the junior high school should be planned to furnish pupils with experiences

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[1] The Junior High School Curriculum, p. 150, Fifth Yearbook, the Department of Superintendence of the National Education Association, Washington: Government Printing Office, 1928.

whereby they would attain a knowledge of those principles and laws that are most valuable socially. These laws and principles should be selected on the basis of their value in making the pupil's world meaningful to him.

In 1932 the Committee on science of the National Society for the Study of Education reported the results of its numerous investigations and experiences in its Thirty-First Yearbook.[2] The major aim of general education as set forth in this report is life enrichment. The members of the Committee agree that this goal may be accomplished by developing an understanding of principles, or generalizations, that have proved most important during the evolution of mankind.[3] The Committee further emphasizes that a program in science for general education should be organized around principles, or generalizations, that are functional in the lives of boys and girls.[4]

The Committee also recommends that facts should be taught only as they can be used to facilitate the functional understanding of principles and the development of their associated scientific attitudes.[5]

In 1938 the Thayer Commission on Secondary School

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[2] A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Illinois: Public School Publishing Company, 1932.

[3] Ibid., p. 43.

[4] Ibid., p. 43.

[5] Ibid., p. 43.

Curriculum of the Progressive Education Association published the report of its findings on the function of science in general education.[6] This commission propounds the idea that scientific instruction should be guided toward satisfying the needs which exist in the basic aspects of living. Thus, subject matter to be included in instruction in science arises from the realm of the pupils' interests.[7]

The Thayer Commission further recommends the development of interpretive understandings as a goal of scientific instruction insofar as these understandings effect notable changes in the individual's behavior.[8] This commission, moreover, refers to a generalization of science as "an interpretive understanding" while the Thirty-First Yearbook Committee calls a generalization a principle.

The reports of both groups agree, however, that the major goal of instruction in science at all grade levels of general education is a functional understanding of scientific principles.

Kilgore[9] ran an experiment in 1941 to determine if

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[6]Progressive Education Association, Commission on Secondary School Curriculum, Science in General Education. New York: D. Appleton-Century Company, 1938.

[7]Ibid., p. 27.

[8]Ibid., p. 55.

[9]William Arlow Kilgore, Identification of Ability to Apply Principles of Physics, Teachers College Contribution to Education, No. 840, pp. 5-19. New York: Teachers College, Columbia University, 1941.

principles should be emphasized in a course of physics. The author constructed a principles test to measure the extent to which pupils were able to apply physics principles in solving new problem situations. The test items were unlike any problems set forth in the textbook the pupils used, and, in addition, they were different from any problem the pupils had been asked to solve previously. For this survey two groups of pupils were used. Each group consisted of 36 pupils taking the course in physics. However, Group I, the control group, took the course during the first semester, while Group II, the experimental group, took the course during the second semester. The same teachers instructed both groups. In teaching Group I, no principles were suggested, while in teaching Group II, principles were emphasized. At the end of each semester the respective groups were given the principles test and the Cooperative Physics Test Form 1934 prepared by the Cooperative Test Service of the American Council on Education. Pupils of each group with identical or comparable records in previous high-school science and with comparable I. Q.'s were paired for analysis of the test scores. Items were scored on the basis of evidence of ability to recall and to apply principles pertinent to the solution of the problem situation. The better results on the tests were obtained by the pupils in Group II.

The author disclosed that a course of study in physics should comprise the experiences useful in aiding and guiding

pupils in acquiring a functional understanding of principles of physics. Another recommendation made as a result of this study was that principles should be sought for in any field of knowledge so that the layman would be better able to solve his problems.

Survey of Important Research Studies Pertaining to the Determination of Principles As Objectives of Science Teaching

As early as 1925 Downing[10] published the opinion that there are three stages of development in the solving of a scientific problem: (1) the accumulation of facts, (2) discovery of the relation and sequence of such facts reduced to generalizations, and (3) discovery of the approximate causes that underlie such laws or principles.

In planning a course of study in science for the elementary grades Craig[11] stated that "the problem in the elementary school in regard to science is not so much that of training boys and girls to become scientists, as it is of helping them to become intelligent laymen." To accomplish this purpose a course of study should be planned that will develop certain objectives which conform to the facts, principles, generalizations, and hypotheses of

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[10]Elliot R. Downing, Teaching Science in the Schools, p. 53. Chicago: University of Chicago Press, 1925.

[11]Gerald S. Craig, Certain Techniques Used in Developing A Course of Study in Science for the Horace Mann Elementary School, Teachers College Contribution to Education, No. 276, pp. 12-13. New York: Teachers College, Columbia University, 1927.

science essential to the understanding of natural phenomena which challenge children.

In a study to determine the amount of space in textbooks devoted to principles of science Heinemann[12] analyzed 20 textbooks of general science. In this study a principle of science was defined as a "statement of relationship frequently causal in nature between two facts." It was noted that only a little more than 12 percent of all the reading space was devoted to principles. It was found that the authors of the various books treated principles very briefly. Furthermore, the authors showed little agreement as to which principles were of the greatest importance. This study recommended that the development of a few principles with several applications is much better than teaching a great many principles with only a few applications.

In 1934, Downing[13] made a survey of more than a dozen masters' theses written at the University of Chicago and from them drew up 96 principles considered necessary in chemistry, physics, and biology. The principles were classified and arranged in order of importance as determined by the amount of subject matter each principle required to make it intelligible.

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[12]Ailsie M. Heinemann, "A Study of General Science Textbooks," General Science Quarterly, XIII (November, 1928), 11-23.

[13]Elliot Rowland Downing, An Introduction to the Teaching of Science, pp. 39-48. Chicago: University of Chicago Press, 1934.

In an attempt to determine the important principles of science which are suitable as goals of instruction in elementary science grades I-VI, inclusive, Robertson[14] completed an extensive investigation in 1934. Four masters' theses and another unpublished study from the University of Michigan and three published studies by Downing and two other unpublished studies from the University of Chicago were analyzed to secure lists of major and minor principles. Criteria for a principle were set up and a jury of four members of the Department of Science, University of Michigan High School, compared each principle with the criteria and those that did not adhere to the criteria were discarded. Following are the criteria used in his study: To be a principle a statement

Must be a comprehensive generalization
Must be true without exception within the limitations specifically stated
Must be a clear statement of a process or interaction
Must be capable of illustration so as to gain conviction
Must not be a part of a larger principle
Must not be a definition
Must not deal with a specific substance or variety or with a limited group of substances or species

A total of 243 principles were found which conformed to the established criteria. This list was then shown to 15 science teachers who checked the principles using a five point scale to determine their appropriateness as

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[14] Martin L. Robertson, "The Selection of Science Principles Suitable as goals of instruction in Elementary Science," Science Education, XIX (February, 1935), 1-4; (April, 1935), 65-70.

goals of instruction in the elementary grades. In the opinion of the evaluators many of the principles were unsuited for the lower grades. Thus, the final list consisted of 113 principles suitable as goals of instruction for grades I through VI.

Pruitt[15] made a study to determine the concepts and generalizations in the field of chemistry which are of most distinctive value to man in interpreting his environment. Over fifty-thousand pages of material including several issues of three popular literary magazines, issues of four popular scientific magazines and one chemical journal, questions from three nationally known examinations, numerous books on various phases of science, particularly chemistry, and one years issue of several newspapers were examined. By using the same criteria for a principle as were used previously by Robertson a final list of 135 generalizations related to chemistry was formulated with the principles arranged in the approximate order of their importance.

Wise[16] carried out an extensive and comprehensive investigation of the principles of the physical sciences. His criteria for a principle, while similar to Robertson's

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[15]Clarence Martin Pruitt, An Analysis, Evaluation, and Synthesis of Subject-Matter Concept and Generalizations in Chemistry. Doctor's Dissertation, Teachers College, Columbia University, 1935. Distributed through Science Education.

[16]Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education," Science Education, XXV (December, 1941) 371-79; XXVI (Junuary, 1942) 8-12.

were more concise. Following are the criteria used in this study:

> To be a principle a statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.
> It must be true without exception within limitations specifically stated.
> It must be capable of illustration.
> It must not be a definition.

Using separate lists of principles developed by Arnold, Hartman and Stephens, Pruitt, and Robertson and employing a reliable technique, Wise[17] formulated a defensible list of 272 principles of physical science. Of these 272 principles 264 were arranged in the relative order of their importance for general education grades I-XIV, inclusive. Included in this composite list of principles were principles of chemistry, geology, and physics (including astronomy and meteorology).

The Thirty-First Yearbook Committee recommended that an assignment of scientific generalizations to definite grade levels be considered in terms of increasingly enlarged and mature understandings of certain principles established as goals of instruction at every level of development. Therefore, this study by Wise represents a partial solution to the problem inasmuch as it establishes the important principles found in the field of the physical sciences.

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[17]Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education. Unpublished doctor's dissertation, University of Michigan, 1941.

In order to determine what principles of science are found in textbooks for the elementary grades, Reek[18] made an investigation of four series of textbooks written specifically for grades I through VI. It was found that authors of these books did not treat principles as the Thirty-First Yearbook Committee had suggested and that the authors dwelt more on physical than on biological principles. Some of the authors did not attempt to use principles at all.

In 1944, Martin[19] made a comprehensive investigation of the principles of the biological sciences. The following criteria for a principle were established for use in this study:

(1) It must be a comprehensive generalization which resumes the widest possible range of facts within the domain of facts with which it is directly concerned. The facts resumed in the generalization must denote:
   a. Objects and/or events and the relation between them.
   b. Properties.
(2) It must be scientifically true. To satisfy this criterion:
   a. It must be verifiable; i.e. it must be stated so that it suggests, directly or indirectly, a definite operation of observations or experiments whereby its truth value can be tested or verified.
   b. It must be consistent with the body of

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[18]Doris Lucille Reek, A Study of the Principles of Science Found in Four Series of Textbook of Elementary Science. Unpublished master's thesis, University of Michigan, 1943.

[19]W. Edgar Martin, "A Determination of the Principles of the Biological Sciences of Importance for General Education," Science Education, XXIX (March, 1945), 100-105; XXIX (April-May, 1945), 152-163; XXIX (February, 1945), 45-52; School Science and Mathematics, (June, 1945), 543-550.

> accepted scientific knowledge, and except for a few limiting or singular exceptions, with all the data (facts) relevant to it.

In determining a defensible list of 300 principles related to the field of biological sciences, Martin helped to solve further the problem set forth by the Thirty-First Yearbook Committee. Martin used the same reliable technique used previously by Wise. Since Wise had already made a defensible list of principles related to the field of physical science, this list of principles related to the field of biological science completed the problem of establishing certain principles of science to be used as goals of instruction for general education at all grade levels.

To determine those science principles which should become the knowledge objectives of the general science course, Fleish[20] made a survey based upon the scientific interests of pupils in grades VII through XII in four Massachusetts communities. A list of 60 principles was formulated from the numerous questions submitted by the pupils. Ten textbooks of general science were then analyzed to determine which of the 60 principles were included in them. It was found that while most of the textbooks did give some space to most of the listed principles, the principles were not stated in clear and

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[20]Sylvia Fleish, The Formulation of the Science Principles That Should Become the Objectives of General Science Teaching in the Junior High School. Unpublished master's thesis, Boston University, 1945.

concise language.

In a study to determine the principles of science found in textbooks written since publication of the Thirty-First Yearbook, Jones[21] analyzed seven textbooks of general science written specifically for the ninth-grade level of general education. A list was made of the 146 principles which satisfied the following criteria: A principle is a comprehensive generalization which

Is stated definitely, not inferred
Is true but with rare exceptions within the limitations set by the statement
Is a clear statement of a dynamic process or of an interaction
Is not merely a definition or a description
Is demonstrable experimentally
Does not deal with specific substances or varieties
Has meaning outside of the context

Jones's study discloses that authors of textbooks have not recognized the proven value of organizing the subject matter in terms of principles. It was also found that there is a wide diversity in the number of principles found in the various textbooks. Furthermore, there is little or no agreement among authors regarding what principles should be included in a ninth-grade textbook of general science.

In 1947, the Forty-Sixth Yearbook Committee[22] of the

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[21] Ruth V. Jones, A Study of the Principles of Science Found in Ninth Grade Textbooks of General Science. Unpublished master's thesis, University of Michigan, 1946.

[22] Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I, pp. 19-41, 137-208.

National Society for the Study of Education pronounced for principles as objectives of the teaching of science. Furthermore, the Committee believed that principles may well serve as a basis for the organization of instructional materials in science.

Survey of Important Research Studies Pertaining to the Effectiveness of Teaching Principles In Terms of the Retention of Learning

In order to determine the relative retention by pupils of factual knowledge, their ability to explain every day happenings, and their ability to generalize from facts, a battery of three tests was given to a group of ninth-grade pupils four months, and again twelve months, after they had completed a course in general science. One test required knowledge of scientific facts; a second test necessitated explanations of commonly seen phenomena; a third test sought the pupils ability to generalize from given facts. The findings in this study show that, although there was considerable loss in information regarding science, there was practically no loss in ability to explain the phenomena that occur every day and the ability to generalize from facts.[23]

In a study conducted by Johnson[24] at the University

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[23]Ralph W. Tyler, "What High School Pupils Forget," Educational Research Bulletin, Ohio State University, IX (November 19, 1930), 490-492.

[24]Palmer O. Johnson, "The Permanence of Learning in Elementary Botany," The Journal of Educational Psychology, XXI (January, 1930), 37-47.

of Minnesota, an objective type test was given to three groups of elementary botany students at the end of three, fifteen, and twenty-seven months, respectively, following completion of the course. Results of these tests show that there is a rapid loss in factual knowledge between the three and the fifteen month period while there is a very gradual loss after the fifteen months.

Wert[25] made a study at Ohio State University in which six tests were given to all the students in the elementary zoology classes to determine their retention of certain knowledge, abilities, and skills. In May of each of the following three years similar tests were again administered to those students who had taken the elementary course but who had not continued in the field of zoology to determine the amount of learning that had been retained at the end of one, two, and three years following completion of the course. The results of this study indicate that whereas there is a great loss in factual knowledge, with the loss increasing with the passage of each year, there is, however, no loss in the ability to apply principles in solving new problem situations and, furthermore, this ability increases with the passage of time.

An investigation involving 82 students taking the course in elementary zoology at Ohio State University was made to determine their relative retention of learning.

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[25]James E. Wert, "Twin Examination Assumptions," Journal of Higher Education, VIII (March, 1937), 136-140.

It was found that fifteen months after the students had completed their course they had forgotten much of the factual knowledge while for the same period of time their ability to apply scientific principles to new situations had increased.[26]

A study was made at three high schools in Ohio in 1934-35-36 to ascertain the amount of retention of certain knowledge, abilities, and skills gained from studying a course in high school chemistry. Five tests were given to the chemistry classes as pre-tests at the beginning of the course. The tests were again administered nine months later. The tests required knowledge of chemical facts, terminology, formulas and valence, symbols, balancing equations, and application of principles. The results reported by Frutchey[27] show that the greatest amount of retention was in the application of principles.

In 1942 Ziegler[28] reported the findings in an investigation made to determine the numbers of facts as well as which facts were best retained by pupils three years after they had studied general science. It was further undertaken to determine which facts were best

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[26]Ralph W. Tyler, "Permanence of Learning," Journal of Higher Education, IV (April, 1933), 203-204.

[27]F. P. Frutchey, "Retention in High School Chemistry," Educational Research Bulletin, Ohio State University, XVI (February 17, 1937), 34-37.

[28]Robert T. Ziegler, "A Study of Factual Retention in General Science," Science Education, XXVI (February, 1942),

retained by college freshmen who had just completed a one-year course in general science.

Thirty-five seniors in high school, who had studied no other science since their course in ninth-grade general science, and a matched group selected from the freshman classes in general science were administered a multiple-choice test near the end of the school year.

The results of this experiment indicated significant differences between the two groups. The freshmen excelled in every part of the examination. The high school seniors had retained only those facts which met their needs of everyday living.

This study shows that even though some facts are practical and useful schools place too much emphasis on facts that will not be retained.

Survey of Important Research Studies Pertaining to the Determination of Experiments to be Used for Developing Principles of Science

Both Wise and Martin have stated as parts of their criteria for a principle that a principle must be capable of demonstration. There have, however, been no research studies to determine experiments which may be used in developing the various principles of science at different grade levels for general education.

Summary of Research Studies

A review of the foregoing investigations and surveys

indicates that scientific principles and generalizations are recognized and justified as objectives of science teaching at all grade levels for general education.

Downing, at the University of Chicago, seems to be the person to be credited with the first emphasis on generalizations as goals for science instruction in general education. His work also produced a rapid shift from mere factual learning as an end in itself to the use of facts as a means to an end, the end being the formulation of generalizations which can be used in solving new problem situations.

Curtis, at the University of Michigan, should be given much credit for the leadership given Robertson, Wise, and Martin who have done the greatest amount of work in establishing the essential principles that should be of value to science instruction at all levels of general education. Robertson's work in 1934 was to be the groundwork for Wise and Martin in compiling their defensible lists of physical science principles and biological science principles, respectively.

These two extensive investigations have established a definite concept of a principle since they employed similar criteria in determining the scientific principles of all fields of science taught in general education grades I-XIV, inclusive.

The studies made by Tyler, Johnson, Wert, Frutchey, and Ziegler give substantial evidence that the old idea of

facts as an end in themselves can be no longer justified since facts that are not related to principles are soon forgotten. Educators must shift their emphasis to the teaching of facts only as a means of developing scientific principles to be used in solving new problem situations.

The Problem of This Investigation

This investigation is undertaken in an attempt to determine what principles of science are found in four ninth-grade textbooks of general science, published or revised since 1940, other than those textbooks analyzed by Jones at the University of Michigan, as a contribution toward the determination of the principles of science found in all textbooks of general science with a copyright date later than 1940. It is further undertaken in this investigation to make a defensible assignment to the principles, found in the four textbooks analyzed, of the experiments, the performance of which should help pupils of the ninth grade develop an understanding of the principles.

Statement of the Problem

This investigation is made (1) to determine the principles and experiments of physical and biological science found in four ninth-grade textbooks of general science; and (2) to assign to these principles the experiments, the performance of which should help pupils

of the ninth grade develop an understanding of the principles.

Scope and Limitations of This Investigation

This investigation is limited to the analysis of four textbooks of general science written specifically for the ninth grade and with a copyright date later than 1940.

Only those principles found in these four textbooks will be used in this investigation even though the possibility exists that there may be other principles suitable as goals of instruction at the ninth-grade level.

Only those experiments found in the same four textbooks will be assigned to principles.

CHAPTER II

RESEARCH

Statement of the Problem

The purpose of this part of the investigation is to determine the principles of physical and biological science found in four ninth-grade textbooks of general science.

Techniques Employed

Criteria for the Selection of Textbooks for Analysis

In order that suitable textbooks be used for this investigation, the following criteria for the selection of textbooks for analysis were established: The textbooks must have been:

Published or revised since the year 1940
Published by a well-known publishing house.
Written specifically for use at the ninth-grade level of general education.
Available for use at the time the investigation was started.

The books selected were:

Meister, Morris; Keirstead, Ralph E.; and Shoemaker, Lois M., Science for A Better World, The Wonderworld of Science Series. New York: Charles Scribner's Sons, 1946

Smith, Victor C. and Trafton, Gilbert H., Using Science, The Science in Modern Life Series. Chicago: J. B. Lippincott Company, 1946.

Powers, Samuel Ralph; Neuner, Elsie Flint; Bruner,

Herbert Bascom; and Bradley, John Hodgdon, Using Our World, Adventuring in Science Series. Boston: Ginn and Company, 1946

Dull, Charles E.; Mann, Paul B.; and Johnson, Philip G., Modern Science in Man's Progress, Modern Science Series. New York: Henry Holt and Company, 1942

Criteria for the Selection of Principles from Textbooks

In a doctoral dissertation written in 1941 Wise[1] listed 264 principles of physical science in the relative order of their importance for general education grades I-XIV, inclusive. Eight other principles were excluded from the list in accordance with the criteria and techniques employed.

In a similar doctoral dissertation written in 1944, Martin[2] listed 300 major principles of biological science in the relative order of their importance for general education grades I-XIV, inclusive. Two-hundred minor principles were excluded from the list in accordance with the criteria and techniques employed.

Inasmuch as only these investigations contain comprehensive lists of principles of the physical and biological sciences which were determined by defensible research techniques, it is considered by this investigator

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[1]Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education. Unpublished Doctor's dissertation, University of Michigan, 1941.

[2]William Edgar Martin, A Determination of the Principles of the Biological Sciences of Importance for General Education. Unpublished Doctor's dissertation, University of Michigan, 1944.

that Wise's list of 264 principles of physical science and Martin's list of 300 principles of biological science are the best available lists of such principles. Therefore, scientific generalizations for the purposes of this investigation are principles of science only if they are included as a comprehensive generalization, found in either Wise's or Martin's lists of scientific principles for purpose of general education.

Accordingly, a set of criteria for the selection of principles from textbooks had to be established. In 1946 Blanchet[3] developed four criteria to be used in selecting statements of principles from textbooks. Blanchet's investigation was made at the junior-college level of general education; therefore, his criteria called for complete statements of the various principles. Since principles should, in the opinion of many leaders in the field of science education, be introduced at one grade level and further developed and enlarged at higher grade levels, then portions of principles would in some cases be acceptable at the junior-high-school level. Therefore, for the purpose of the selection of principles of science from textbooks of general science for grades 7, 8, and 9, a group comprising the Seminar in Science Education at Boston University, 1946-47, modified Blanchet's criteria

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[3]Waldo Emerson Blanchet, A Basis for the Selection of Course Content for Survey Courses in the Natural Sciences, p. 118. Unpublished Doctor's dissertation, University of Michigan, 1946.

to read as follows: A statement is considered to be that of a particular principle:

1. If it expresses completely the idea embodied in the original statement of the principle in Wise's or in Martin's list; or

2. If, though it does not state all of the elements of the principle, it is implied by the author or authors as being the said principle; or

3. If it unmistakably implies the principle and can be reworded so that the principle is stated; or

4. If, though it does not state the principle in full, it can be combined justifiably with another statement in the same paragraph or section, which together state the principle or can be reworded to do so.

Method of Analysis of Textbooks for Principles

Before an analysis could be made of the textbooks the master lists of principles by Wise and Martin had to be catalogued in order to eliminate the necessity of reading the complete lists of physical and biological science principles each time a page was analyzed. Comprehensive topical headings were selected for grouping the physical science principles. Each of the 264 principles of physical science in Wise's list was then placed under one of the following topical headings: Air and Other Gases (including Pressure), Astronomy (including Gravitation), Earth's Surface, Fire and Heat, Light, Magnetism and Electricity, Matter, Energy, Sound, Water and Other Liquids, Weather and Climate, and principles Involving Mathematical Calculation. Comprehensive topical headings were also selected for grouping the biological principles.

Each of the 300 major biological principles in Martin's list was then placed under one of the following main topic headings: Adaptations for Survival, Conservation, Evolution, Foods and Energy (including Growth), Functions of Living Things, Green Plants, Health, Reproduction and Breeding, and Structure of Living Things.

With the principles classified and criteria for the selection of principles from textbooks established, the four textbooks of general science selected were then analyzed page by page to determine the principles included in them. Whenever a principle was found, it was written on a three-by-five file card with the book and page number at the top of the card. Some principles were copied word for word; others were paraphrased. In addition to this, the statement selected as being the principle or part of the principle was underscored in the textbook. If the principle appeared later in the same book or in another book, the book and page numbers were again placed at the top of the card on which the principle was written. In every case, the statement selected as being a principle or part of a principle was underscored in the textbook in which it was found. In this manner a set of cards was compiled with one principle on each card accompanied at the top of the card by the total number of books containing the principle, along with the number of the page or pages on which the principle was found in the respective books. In many instances the complete principle as stated by Wise or Martin was not found in the textbooks written for the

ninth-grade level of general education. Instead, only parts of a principle were found. These parts of principles are hereafter in this investigation considered to be minor principles, the principles in Wise's and Martin's lists being considered major principles or generalizations.

Index of Reliability for the Selection of Principles from Textbooks

Since the subjective factor of human judgment in the selection of principles from textbooks is liable to variability, the reliability of the investigator's judgment in the selection of principles from textbooks was determined by reanalyzing 100 pages selected at random from one of the four textbooks two months after the first analysis was made. This technique was similar to that used by Robertson, Wise, Martin, and Keeslar at the University of Michigan. The "index of reliability" is defined as: $\frac{A}{A + B + C}$ when

A is the number of principles common to two analyses of the same source material.

B is the number of principles found only in the first analysis.

C is the number of principles found only in the second analysis.

Book number one was selected for the reanalysis since it had been the first book analyzed by the investigator and would perhaps give a lower coefficient of re-

liability on reanalysis than would any one of the other three. The investigator, being more familiar with the lists of principles, probably made a more accurate analysis of the second, third, and fourth textbooks than he did of the first one. The original analysis of book number one produced sixty-one principles. In the second analysis, one of these principles was not again found but two new principles were found, thereby bringing the final total number of different principles to sixty-three. Sixty of these principles were common to both analyses. Using the above formula, the "index of reliability" proved to be 95.2 percent. This indicated that the reliability of the investigator's judgment was sufficiently high.

Criteria for the Statement of a Principle for Comprehension at the Ninth-grade Level

The following criteria for the statement of a principle for comprehension at the ninth-grade level were adopted by fifteen science teachers in a Seminar in Science Education, Boston University, 1946-47, and were adhered to in the formulation of principles in this investigation:

To be a scientific principle for comprehension at the ninth-grade level, a statement:

1. Must be a comprehensive generalization or a part of a comprehensive generalization.
2. Must be true without exception within the limitations specifically stated.
3. Must not be a definition.
4. Must be demonstrable experimentally.

5. Must not deal with specific substances.

All principles, other than duplicates, found in the four textbooks analyzed which adhered to the above five criteria of a principle were then assigned by the investigator to the related major principles in Wise's list of 264 principles of physical science, or in Martin's list of 300 biological principles.

Validation of the Statements of Principles for Comprehension at the Ninth-grade Level and of the Assignment of Those Principles to Major Principles of Physical Science and/or Biological Science

The validity of the investigator's judgment in the statement of principles found in the textbooks analyzed and in the assignment of those principles to major principles of physical science in Wise's list or of biological science in Martin's list was determined by the judgment of a specialist* in the teaching of science. He checked every principle (1) for conformability to the five criteria established for the statement of a principle, (2) for comprehension at the ninth-grade level, and (3) for correct assignment to the related major principle or principles in Wise's or Martin's list. All statements of principles judged by the specialist as not conforming to the criteria and which he could not reword to conform were deleted from the final list of principles. Furthermore, if the specialist thought that the language in the statement of a principle was not suitable for the ninth-grade level of com-

*Vaden W. Miles, Assistant Professor of the Teaching of Science, Boston University.

prehension, he reworded the principle to make it comprehensible at that grade level.

Moreover, principles judged by the specialist not to be correctly assigned by the investigator to the related major principle or principles in Wise's or Martin's list were so assigned by the specialist to the related major principle or principles. Thus, the statements of the scientific principles for comprehension at the ninth-grade level and their assignments to related major principles in Wise's or Martin's list were validated.

Table I is a listing of various major principles from the lists by Wise and Martin recorded as major or minor principles as found in the four textbooks. As previously stated, in many instances the complete principle as stated by Wise or Martin was not found in the textbooks written for the ninth-grade level of general education. Instead, only parts of a principle were found. These parts of principles are here considered to be minor principles, the principles in Wise's and Martin's lists being considered major principles or generalizations.

In Table I, all of the major principles found in whole or in part in the analysis have been stated with related minor principles so found included under them. Credit was given a particular textbook only for that part of a principle which was included in it.

Each textbook has been given a symbol letter representing the name of the first author listed on the title

page. Thereafter, M represents the book written by Meister, Keirstead, and Shoemaker; S the book written by Smith and Trafton; P the book written by Powers, Neuner, Bruner, and Bradley; and D the book written by Dull, Mann, and Johnson.

Shown in Table I for each major principle or each related minor principle found in four ninth-grade textbooks of general science are: the textbook in which the principle appeared, the frequency of recurrence (T) of a major or minor principle in all four books analyzed, and the total number of different books (N) in which the major or minor principle appeared.

TABLE I

MAJOR AND MINOR PRINCIPLES OF SCIENCE FOUND IN FOUR NINTH-GRADE TEXTBOOKS OF GENERAL SCIENCE

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Heat						
Solids are liquified and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.						
*When solids are heated, they are changed to liquids, and when liquids are heated, they are changed to vapor.	1				1	1
The rate of evaporation of a liquid varies with the temperature, area of exposed surface, nature						

*Table I is read thus: The statement "When solids are heated...etc." is a minor principle of the major principle formulated by Wise and to which the minor principle is assigned. It was found in book M once but did not appear in books S, P, or D. The number of different textbooks (N) in which the principle appeared was 1. The total number of times (T) the principle appeared in the four textbooks was 1.

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
of the liquid itself, and saturation and circulation of the gas in contact with the liquid.						
As liquids are heated, the molecules escape more rapidly because they move faster.	1				1	1
The principle cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure.						
A mass of air pushes a second mass of air when the pressure of the second mass of air becomes less.	2				1	2
Winds are caused by differences in pressure which are the results of differences in temperature.	1	1			2	2

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
When two bodies of different temperature are in contact, there is a continuous transference of heat energy from the body of higher temperature to the one of lower temperature, the rate of which is directly proportional to the difference of temperature.						
When two bodies of different temperature are in contact, there is a continuous transference of heat energy from the body of higher temperature to the one of lower temperature.		1			1	1
Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.	2	2	2		3	6
Heat is liberated when a gas is compressed, and is absorbed when a gas expands.	2				1	2
Heat is liberated when a gas is compressed.		1	1		2	2
Heat is transferred by convection in currents of gases or liquids, the rate of transfer decreasing with an						

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
increase in the viscosity of the circulating fluid.						
Heat is transferred by convection in currents of gases and liquids.		1	1		2	2
The higher the temperature of the air, the greater the amount of moisture required to saturate it.	1	2			2	3
Heat is conducted by the transfer of kinetic energy from molecule to molecule.	1				1	1
Condensation will occur when a vapor is at its saturation point, if centers of condensation are available and if heat is withdrawn.						
When air is cooled sufficiently, the moisture in it condenses.	1	2			2	3
The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant.	1	1			2	2
If the volume of a confined body of gas is kept constant, the pressure is						

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
proportional to the absolute temperature.	1			1	2	2
The average speed of molecules increases with the temperature and pressure; conversely, the temperature and pressure increase as the average speed of molecules increases and decrease as the average speed of molecules decreases.	1				1	1
Bodies of land heat up and cool off more rapidly and more readily than bodies of water.		1			1	1
Light						
When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass from a dense to a rarer medium, they are bent away from the normal.				2	1	2
Refraction of bending of light rays occurs when light passes through objects of different densities.		2	1		2	3
If a beam of light falls on an irregular surface, the rays of light are scattered in all directions.		1	1	1	3	3

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Parallel light rays may be converged or focused by convex lenses or concave mirrors; diverged by concave lenses or convex mirrors.		2			1	2
Parallel light rays may be focused by convex lenses.	1			1	2	2
A convex lens brings light rays together while a concave lens spreads the rays apart.			1		1	1
Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.		1		2	2	3
The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.	1	1	1	1	4	4
Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.		1	2	1	3	4
Light travels in straight lines in a medium of uniform optical density.						
Light travels in straight lines.		1	1	1	3	3

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
When light is reflected, the angle of incidence is equal to the angle of reflection.		1		1	2	2
The colors of objects depend upon what light rays they transmit, absorb, or reflect.		1	1	1	3	3
The intensity of illumination decreases as the square of the distance from a point source.				1	1	1
The darker the color of a surface, the better it absorbs light.		1		1	2	2
An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.		1			1	1
Sound						
Sound is produced by vibrating matter and is transmitted by matter.	1	3	2	1	4	7
The higher the pitch of a note, the more rapid the vibrations of the producing body.			2		1	2

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.						
The higher the density of a substance, the faster sound travels in it.		1			1	1
Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.		1			1	1
The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases as the square of the distance from the source.						
Loudness of a sound depends upon the force used to produce it.		1	1		2	2
Electricity						
An electrical charge in motion produces a magnetic field about the						

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.						
Every wire carrying a current is surrounded by a magnetic field.		1	1	1	3	3
An electrical current will flow in the external circuit when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.						
An electric current is produced when two different metals separated by an acid solution are acted upon chemically by the solution.	1	1	2	1	4	5
Electrons will flow from one point to another along a conductor if this transfer releases energy.	1		1	1	3	3
Like electrical charges repel and unlike electrical charges attract.	1	2	2	1	4	6
All materials offer some resistance to the flow of an electric current, and that part of the electrical energy used in overcoming this resistance is						

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
transformed into heat energy.	2	2		3	3	7
An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of a magnetic field.	1	1	1	1	4	4
Like magnetic poles always repel each other and unlike magnetic poles always attract each other.	1	1		1	3	3
In an uncharged body there are as many protons as electrons and the charges neutralize each other while a deficiency of electrons produces a plus charge and an excess of electrons produces a negative charge.	1		1	1	3	3
In a transformer the ratio between voltages is the same as that between the number of turns.	1	1		1	3	3
A magnet always has two poles, and is surrounded by a field of force.		1		1	2	2

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Energy						
When waves strike an object, they may either be absorbed, transmitted, or reflected.						
When light waves strike an object, they may either be absorbed, transmitted, or reflected.	1	2	1	1	4	5
When a sound wave strikes a solid object, its energy may be absorbed often causing the object to vibrate or the wave may be reflected.		1			1	1
Energy can never be created or destroyed (except in nuclear physics); it can be changed from one form to another with exact equivalence.	1	1			2	2
Energy is often transmitted in the form of waves.	1	1	1	1	4	4
The more nearly vertical the rays of radiant energy the greater the number that will fall upon a given horizontal area, and the greater is the amount of energy that will be received by that area.						

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The greatest amount of radiant energy is absorbed by a surface at right angles to the rays.		1			1	1
Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional to the square of the distance from the source.						
Radiant energy travels in waves along straight lines.		1			1	1
Matter may be transformed into energy and energy into matter, the sum-total, matter plus energy, remains constant.	1	2			2	3
Mechanics						
Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.						
There is a force called gravity which exerts a pull between any two objects no matter what their size nor where they are.			1		1	1

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The force of attraction between any two bodies decreases as the distance between them increases.				1	1	1
Movements of all bodies in the soalr system are due to gravitational attraction and inertia.	1				1	1
Bodies moving in the solar system attract each other by a force called gravity.		1		1	2	2
The natural movements of air, water, and solids on the earth are due chiefly to gravity plus rotation of the earth.						
All bodies are attracted to the earth by a force called gravity.	1		2	1	3	4
Gravity causes liquids to flow down hill.		1	1		2	2
At any point on the earth's surface, all bodies fall with a constant acceleration which is independent of the mass or size of the body, if air resistance be neglected.		1			1	1

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The pressure of a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as the depth and average density of the fluid.						
The pressure under water becomes greater as the depth becomes greater.	1		1		2	2
A body emersed or floating in a liquid is buoyed up by a force equal to the weight of the fluid displaced.		1	2	1	3	4
The atmospheric pressure decreases with increasing water vapor content, other things being equal.	1				1	1
When pressure is applied to any area of a fluid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the fluid.		1			1	1
In moving air, wind pressure increases as the square of the velocity.		1			1	1

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The pressure at a point in any fluid is the same in all directions.	1	1			2	2
Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.				1	1	1
The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.						
The energy possessed by a moving object is called kinetic energy.		1	1		2	2
When the resultant of all the forces acting on a body is zero, the body will stay at rest, if at rest, or it will keep in uniform motion in a straight line, if it is in motion.	2	1	1		3	4
A body in motion tends to remain in motion.				1	1	1
Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotation.				1	1	1

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of the force.		1			1	1
The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that is done in order to bring it into the specified condition.						
The energy which a body possesses on account of its position is called potential energy.		1	1	1	3	3
A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.		1			1	1
Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together and independent of area of contact.						
Sliding friction is dependent upon the nature and condition of the rubbing surfaces.			2		1	2

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.			1	1	2	2
In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.			1	1	2	2
In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.			1	1	2	2
Geology						
The earth's surface may be elevated or lowered by interior forces.						
The earth's surface may be elevated by interior forces.	1				1	1
When elevations or depressions are created upon the surface of the earth, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions.	1	2			2	3

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Streams, generally, are lowering the surface in some places and building it up in other places.		1			1	1
Streams, potentially, have a regular cycle; youth, maturity, and old age.		1			1	1
Glacial conditions are as a rule approached by increasing latitudes or altitudes.		1			1	1
Chemistry						
All substances are made up of small particles called molecules which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.			1		1	1
All substances are made up of tiny particles called molecules.	1	1			2	2
All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.	1				1	1

TABLE I (CONTINUED)

Principles of Physical Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional differences in atomic weight; i.e. isotopes) but different in different elements.	1				1	1
Atoms of all elements are made up of protons, neutrons, and electrons, and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.	1	2			2	3
Atoms of all elements are made up of protons and electrons.			1	1	2	2
The total mass of a quantity of matter is not altered by any chemical changes occurring among the materials composing it.	1	1			2	2
The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.	1	1			2	2
Elements may be changed into other elements.	1				1	1

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The cell is the unit of structure and function in all organisms.		1			1	1
Every cell consists essentially of a mass of protoplasm which is usually differentiated into a central portion, the nucleus, and an outer portion, the cytoplasm.						
Every cell consists of a mass of protoplasm, including the central part which is called the nucleus.		1			1	1
Cells are organized into tissues, tissues into organs, and organs into systems, the better to carry on the functions of complex organisms.		1			1	1
Protoplasm is the physical basis of all life.	1	1			2	2
In the presence of sunlight the chloroplasts of chlorophyll-bearing plants convert carbon dioxide and water into intermediate substances, and these into sugar, and that into starch, and liberate oxygen; thus, directly or indirectly, producing practically all the food in the world.		1			1	1

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Green plants are the source of practically all food.	2	1		1	3	4
The forms of all chlorophyll-bearing plants are adapted for carrying on photosynthesis.				2	1	2
A balance in nature is maintained through interrelations of plants and animals with each other and with their physical environment.	1	1	1		3	3
Living things are not distributed uniformly or at random over the surface of the earth, but are found in definite zones and local regions where conditions are favorable to their survival.		1			1	1
All plants and animals are engaged in a constant struggle for energy.		1	2		2	3
The existing forms of life on the earth are not all the forms of life which have existed; there has been a great variety of animals and plants which have passed away.	1	1			2	2

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
The earth's position in relation to the sun is a determining factor of life on earth.		1			1	1
Reproduction is a fundamental biological process that provides for the continuance of life on the earth by providing new individuals.		1			1	1
All life comes from preceding life.	1			1	2	2
In sexual reproduction a male cell from one parent unites with a female cell from the other parent to produce the young (except in a few cases of self-fertilization).	2	1		2	3	5
In sexual reproduction an egg cell and a sperm cell unite to form a new individual.			1		1	1
Reproduction in all organisms is a process of growth in which a single cell or a group of cells is separated from the parent body and develops into a new individual.				1	1	1
The most primitive method of reproduction employed by organisms is the						

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TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
splitting of the whole body into two halves, each of which grows into a complete new individual.	1	1			2	2
Living things, even of the same kind, are never exactly alike, not even with regard to single traits (characteristics) such as color or shape.				2	1	2
Living things alter their types. Present species have not always existed but have originated by descent from others which in turn were derived from still earlier ones and so down to the first living things.	1	1		1	3	3
The first forms of life were altogether independent, but evolution has resulted in the general interdependence of organisms.	1	1			2	2
The present is the key to the past; the succession of fossils in the rocks shows a progressive series from simple to complex.	1	1			2	2
In a cross of the F_2 generation of hybrids the genes, which determine the characters, are						

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
segregated in the gametes so that a certain percent of the offspring possess the dominant character alone, a certain percent the recessive character alone, while a certain percent are again hybrid in nature.						
When individuals of the first hybrid generation are mated with hybrids of the same kind, a certain percent will possess the dominant character alone, a certain percent the recessive character alone, while a certain percent are again hybrid in nature.	1	1	1	1	4	4
All living organisms (except viruses and bacteriophage) carry on the common life processes; reproduction, growth, nutrition, excretion, respiration, and irritability.		1			1	1
The food requirements of every living thing are: fuels capable of yielding, when oxidized, the supply of energy without which life can not continue; materials for growth and for replacement for the slight wearing away of the living tissue involved in						

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
any activity; minerals, the necessary constituents of cell structures, of cell products, and of the bathing fluids of cells.						
Survival of all life depends upon a sufficient supply of food.		1			1	1
The protoplasm of a cell carries on continuously all the general processes of any living body; the processes concerned in the growth and repair or upbuilding of protoplasm (anabolism) and the processes concerned with the breaking down of protoplasm and elimination of wastes from the cell (catabolism). The sum of all these chemical and physical processes is metabolism.						
The whole process of using food and releasing energy from it within the organism is metabolism.		1			1	1
The energy which makes possible the activity of most living things comes at first from the sun and is secured by the organism through the oxidation of food within its body.						
The sun is the earth's main source of energy.	2	1	1	2	4	6

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
Oxidation (combustion) furnishes the essential source of heat in the animal body; and, other factors remaining constant, the more heat so produced, the warmer the animal body.		1		1	2	2
All living cells require oxygen to provide energy or to build new protoplasm.				1	1	1
The oxygen of the atmosphere is removed by animals and returned by chlorophyll- bearing plants.	2	1			2	3
Digestion accomplishes two things - it makes food soluble in water, thus enabling the nutrients to pass through membranes and thereby reach and enter the cells; it reduces complex nutrients (fats, proteins, and carbohydrates) to a simple building material which in turn can be rebuilt into whatever living material or structural feature is necessary at the place os use.		1			1	1
An animal can not live without proteins. They are necessary in cell						

TABLE I (CONTINUED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
growth and maintenance; so, are necessities in the diets of animals. Plants are able to use carbohydrates and nitrates to build up the proteins necessary for growth and maintenance of their cells.	1	1		2	3	4
Starches, fats, and proteins are produced by plants and it is upon these that all animals depend primarily for food.	1	1		2	3	4
Water is essential to all living things because protoplasmic activity is dependent upon an adequate water supply.	1			2	2	3
Organisms, whose fossils are found in any quantity, must have lived and died in the period when the strata in which their remains are found were laid down.	1	1			2	2
The physical and chemical properties of plant and animal protoplasm are similar.	1	1			2	2
Osmosis, the diffusion of molecules of a solvent (usually water) through a semi-permeable membrane						

TABLE I (CONCLUDED)

Principles of Biological Science	Books in Which Principles Occurred					Total Frequency of Occurrence
	M	S	P	D	N	T
(a layer of cells or the membrane of a single cell) from the point of highest concentration of the solvent to a point of lower concentration, with a stoppage of the flow of molecules of the solute, is a basic process in plant and animal physiology.	1	1		2	3	4
The environment acts upon living things, and living things act upon their environment.	1	1		1	3	3

Findings. The total number of different major principles found in the four textbooks was 116. Of these, 80, or 69.0 percent, are principles of physical science, and 36, or 31.0 percent, are biological principles. The frequency of occurrence of principles of physical science varied from 37 to 60 in the four books; of biological science from 5 to 31. The average frequency of occurrence of principles of physical science per book was 43.8 principles; of biological principles per book, 18.3. The frequency of occurrence of principles (physical and biological) varied from 42 to 91 in the four books for an average of 62 principles per book.

CHAPTER III

RESEARCH

Statement of the Problem

This part of the investigation is made (1) to determine the experiments of physical and biological science found in four ninth-grade textbooks of general science; and (2) to assign to science principles the experiments, the performance of which should help pupils of the ninth-grade develop an understanding of the principles.

Techniques Employed

The same four textbooks of general science used in Part I, Chapter II, of this investigation were also used for this part of the investigation.

Criteria for the Selection of Experiments from Textbooks

There have been no research studies to determine experiments which may be used in developing principles of science at the different grade levels for general education. Therefore, criteria for the selection of experiments from textbooks had to be established. The following criterion for the selection of experiments from textbooks was approved by eleven science teachers in a Seminar in Science Education, Boston University, 1946-47 and adhered

to in the selection of experiments from the four textbooks: To be an experiment there must be directions either specific or implied, for the manipulation of apparatus or the observation of material in order to answer a question of science.

Method of Analysis of Textbooks for Experiments

The four textbooks previously selected were again analyzed page by page to determine the experiments included in them. Whenever an experiment which complied with the criterion was found, it was written in question form on a three-by-five file card with the book and page number at the bottom of the card. In addition, the experiment was marked with brackets in the textbook. In this manner a set of cards was compiled with one experiment on each card, and the total number of books containing that experiment at the bottom of each card along with the number of the page or pages on which the experiment was found in the respective books.

Index of Reliability for the Selection of Experiments from Textbooks

To determine the "index of reliability" of the investigator's judgment in the selection of experiments from the textbooks the investigator reanalyzed 100 pages selected at random from one of the four textbooks one month after the first analysis was made. This was the same technique used previously to determine the "index of reliability" of the investigator's judgment in the selection

of principles from the four textbooks. The "index of reliability" is here defined as: $\frac{A}{A \neq B \neq C}$ when

A is the number of experiments common to two analyses of the same source material.

B is the number of experiments found only in the first analysis.

C is the number of experiments found only in the second analysis.

One hundred pages were selected at random from book number one. In the original analysis of book number one, thirty-seven experiments were found. The same experiments were also discovered in the second analysis. Therefore, the final total number of experiments found was the same as the original number of experiments. Using the above formula, the "index of reliability" was found to be 100 percent. It seems reasonable, therefore, to assume that the reliability of the investigator's judgment was sufficiently high.

Assignment of Experiments to Principles Comprehensible at the Ninth-grade Level

In Chapter II of this investigation a list of major and minor principles of science found in four textbooks of general science was formulated. For purposes of this investigation only those experiments which could be used to develop these major and minor principles were retained.

Each experiment was examined to see if it might

reasonably be expected to contribute to the development of an understanding of any of the principles. Those experiments that could not be used were discarded. The purpose of every experiment that could be used was written in question form on the bottom of an individual three-by-five file card on which the particular principle to which the experiment contributed had been recorded. In some instances, it was discovered that one experiment could be used to develop several principles. In such a case, the experiment was written in question form on the bottom of each file card the respective principles were written on. In this fashion, each experiment found in the analysis of the four textbooks was either matched with one or more principles, or was discarded as having no value in the development of scientific principles found in the four textbooks.

Validation of the Statements of the Experiments and of the Assignments of the Experiments to Principles.

The validity of the investigator's judgment in the statements of the purposes of the experiments found in the textbooks analyzed and in the assignment of those experiments to the major and minor science principles also found in these same books was determined by the judgment of a specialist* in the teaching of science. He checked each experiment for its conformability to the criterion

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*Vaden W. Miles, Assistant Professor of the Teaching of Science, Boston University.

of an experiment, and also for its correct assignment to the major and minor principles of science found in the four textbooks. Any experiments judged by the specialist as not conforming to the criterion and which he could not reword so as to conform were deleted from the final list of experiments.

Furthermore, experiments judged by the specialist not to be correctly assigned to principles were so assigned by him to the proper major or minor principles. Thus, the statements of the purposes of the experiments and their assignment to major and minor principles were validated.

Table II shows experiments that can be used in developing understandings of the principles of physical and of biological science.

TABLE II

EXPERIMENTS THAT CAN BE USED IN DEVELOPING UNDERSTANDINGS OF THE PRINCIPLES OF PHYSICAL AND/OR BIOLOGICAL SCIENCE FOUND IN FOUR NINTH-GRADE TEXTBOOKS OF GENERAL SCIENCE

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
Heat					
When solids are heated, they are changed to liquids, and when liquids are heated, they are changed to vapor.					
*If a piece of paraffin wax is placed in a metal dish and heated, what happens to the paraffin? If heat is further applied to the paraffin, what eventually happens?	X				1
Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.					
If a cooled flask is fitted with a piece of glass tubing in a one-hole stopper and a balloon is attached firmly to the glass tubing, what happens when the flask is heated? What happens as the flask is allowed to cool?	X				1

*Table II is read thus: The experiment "If a piece of paraffin wax...etc." is one which contributes to the development of an understanding of the minor principle to which it is assigned. The experiment was found only in book M. Thus, the total number of books (T) in which the experiment was found was 1.

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
If a thin strip of iron and a thin strip of copper or brass are riveted together, what happens when the device is brought near a flame?	X		X		2
What causes a thermometer to change its readings at different temperatures?		X			1
If a flask is fitted with a piece of glass tubing in a one-hole stopper and the outer end is placed in a beaker of water, what happens when the flask is heated with a flame?		X			1
Heat is liberated when a gas is compressed, and is absorbed when a gas expands.					
If the outlet of a bicycle or tire pump is closed, what happens to the barrel of the pump when the piston is rammed downward?	X				1
If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.					
If a rigid, air tight box is filled with a gas and fitted with a thermometer and an aneroid barometer, what can be noticed of the readings on each instrument as the gas is cooled?	X				1

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
Light					
Refraction or bending of light rays occurs when light passes through objects of different densities.					
What appears to happen to a pencil that is put partly under water in a drinking glass?		X			1
What appears to happen to a spoon that is put partly in a glass of water?			X		1
If a penny is placed in a cup and you move your head back slowly until the penny is hidden from view by the edge of the cup, what appears to happen as someone pours water into the cup?		X		X	2
The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.					
If a beam of sunlight is allowed to pass through a glass prism, what is the appearance of the light as it now strikes a piece of white cardboard?	X	X	X	X	4
Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.					
If a beam of light is projected onto several boards of various colors at separate times so that the light is reflected from each					

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
board to a light meter, what is the color of the board that reflects the greatest amount of light?		X			1
Light travels in straight lines.					
If a lamp is arranged behind three cardboards standing in the vertical position and with pin holes in each cardboard, what must be the arrangement of the pin holes in order to sight through them so as to see the lamp?		X			1
When light is reflected, the angle of incidence is equal to the angle of reflection.					
If a ruler is placed in front of a mirror, what is the relation between the angle formed by the ruler and mirror and the angle formed by a second ruler lined up with the image of the first ruler and mirror?		X			1
Sound					
Sound is produced by vibrating matter and is transmitted by matter.					
If a fine wire bristle is attached to the end of a tuning fork with a tiny drop of solder, what happens when the tuning fork is struck and a piece of smoked glass is placed beneath the wire bristle?		X			1

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
If two pieces of rubber are stretched over the end of a narrow glass tube so that one slightly overlaps the other, what happens if you blow into the open end of the tube vigorously enough to cause the pieces of rubber to vibrate?			X		1
If a large tuning fork is struck gently with a wooden hammer, what occurs when the fork is touched to the surface of water in a shallow dish? What happens when the fork is touched to a pith ball suspended by a string?			X		1
If two tuning forks of the same pitch are mounted on different boxes, what happens to the second after the first has been struck and is then made to stop vibrating by touching it with the hand?		X			1
If an electric bell is arranged in a bell jar connected with an air pump, what happens to the ringing sound of the bell as the air in the jar is removed by the pump? What happens as the air is allowed to enter the jar?			X		1
If an alarm clock is set at "repeat" and placed on a rubber pad under a bell jar, what happens as the air is pumped out of the jar? What happens as the air is allowed to enter the jar?		X			1
Loudness of a sound depends upon the force used to produce it.					
How is the loudness of sound					

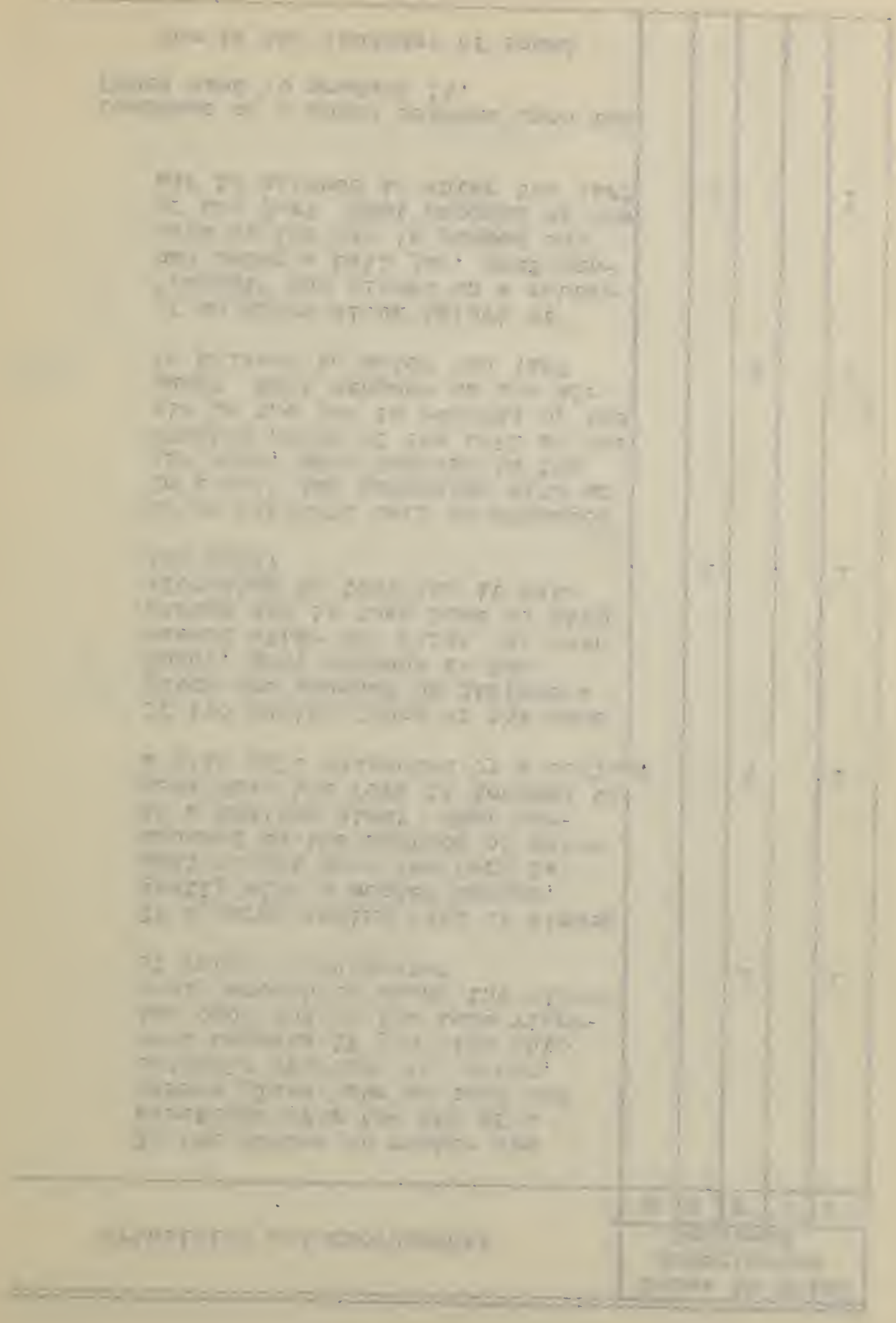

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
affected as a tuning fork is struck harder and harder?			X		1
Electricity					
Every conductor carrying a current is surrounded by a magnetic field.					
If a conducting wire is placed near a magnetic compass so that it lies parallel to the compass needle, what happens when the switch is closed and an electric current is allowed to flow through the wire?			X	X	2
An electric current is produced when two different metals separated by an acid solution are acted upon chemically by the solution.					
If a penny and a nickel (or pieces of copper and zinc) are separated by a piece of paper towel soaked in a very dilute solution of sulfuric acid, what happens when wires attached to a galvanometer are touched to the two pieces of metal?	X				1
If pieces of copper and zinc wire are inserted into a lemon and attached to the poles of a voltmeter, is there evidence of an electric current being produced?		X		X	2
If pieces of copper and zinc metal are suspended in any acid, base, or salt solution, what happens when the pieces are connected to a galvanometer?		X	X		2

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
If a carbon plate and a zinc rod are suspended in a solution of ammonium chloride, what happens when the carbon and zinc are touched simultaneously by wires attached to a door bell?			X		1
Like electrical charges repel and unlike electrical charges attract.					
If a strip of thoroughly dry newspaper one inch wide is folded in the middle and the fold is grasped by the left hand, what happens when the paper is drawn upward quickly between two fingers of the right hand pressed against it?	X				1
If a suspended pith ball is touched by a hard rubber rod rubbed with wool or fur, what happens when the rubber rod is again brought near the ball? When a glass rod rubbed with silk is brought near the ball? If a suspended pith ball is touched by a glass rod rubbed with silk, what happens when the glass rod is again brought near the ball? When a hard rubber rod rubbed with wool or fur is brought near the ball?			X	X	2
If two suspended pith balls are touched by a hard rubber comb run briskly through the hair, what happens? What happens when a glass rod rubbed with silk is brought near the balls? If the two pith balls are touched by a glass rod rubbed with silk, what happens? What happens when a					

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
hard rubber comb run briskly through the hair is brought near the pith balls?		X			1
If two balloons are inflated and suspended side by side, what happens when one of the balloons is rubbed briskly between the hands and then released?				X	1
If a hard rubber rod is rubbed with fur and suspended in a wire stirrup, what happens when a second hard rubber rod rubbed with fur is brought near one end of the suspended rod?	X		X	X	3
If a hard rubber rod is rubbed with flannel, what happens when the rod is brought near some small bits of paper?	X				1
If a hard rubber comb is rubbed vigorously with a piece of wool, what happens when it is brought near small bits of paper?			X		1
All materials offer some resistance to the flow of an electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.					
If one end of a short piece of fine bare copper wire is attached to one terminal of a dry cell and the other end is held against the second terminal, what occurs?	X	X		X	3

[illegible] (continued)

[illegible]	[illegible]				
	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]					
[illegible]				

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of a magnetic field.					
If a penny and a nickel (or pieces of copper and zinc) are separated by a piece of paper towel soaked in a very dilute solution of sulfuric acid, what happens when wires attached to a galvanometer are touched to the two pieces of metal?	X				1
If pieces of copper and zinc wire are inserted into a lemon and attached to the poles of a voltmeter, is there evidence of an electric current being produced?		X		X	2
If pieces of copper and zinc metal are suspended in an acid, base, or salt solution, what happens if the pieces are connected by wires to a galvanometer?		X	X		2
If a carbon plate and a zinc rod are suspended in a solution of ammonium chloride, what happens when the carbon and zinc are touched simultaneously by wires attached to a door bell?			X		1
If a coil of wire is attached to a galvanometer, what happens when a magnet is passed through the center of the coil? What happens when the coil is passed down over the magnet?	X	X	X	X	4

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
Like magnetic poles always repel each other and unlike magnetic poles always attract each other.					
If a large cylindrical magnet is placed on a table and a second cylindrical magnet is rolled towards it, what happens if the north poles of each magnet are opposite each other? If the north pole of one is opposite the south pole of the other?	X				1
If you bring a magnet near a compass, what happens when the north pole of the magnet is presented? The south pole is presented?		X			1
If a bar magnet is suspended in a stirrup, what happens when the north pole of a second bar magnet is presented to the suspended magnet? The south pole is presented?				X	1
A magnet always has two poles, and is surrounded by a field of force.					
If a bar magnet is laid on a table and covered with a sheet of glass, or paper, how do iron filings sprinkled on the sheet arrange themselves when the sheet is tapped lightly with a pencil?		X		X	2

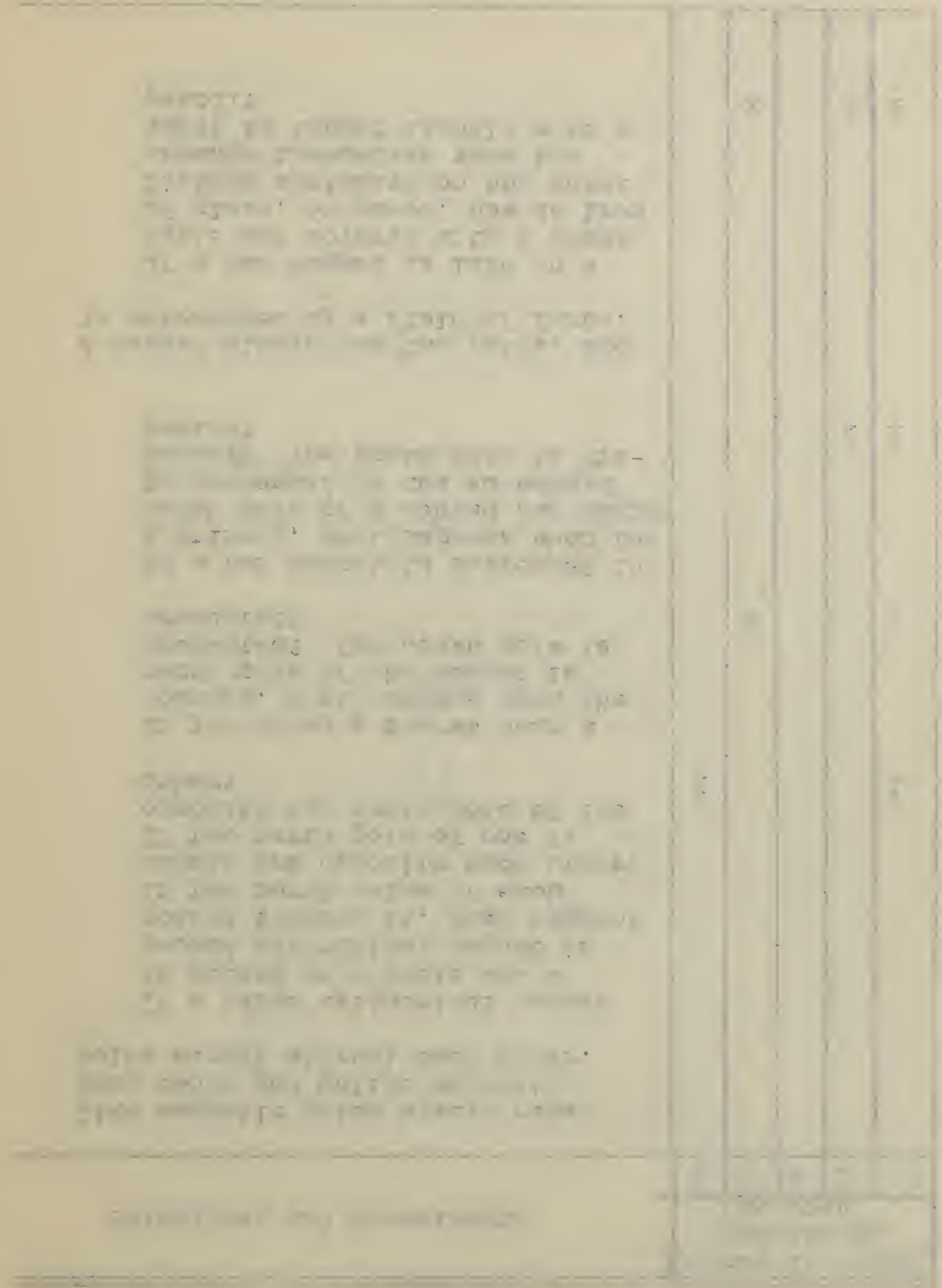

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
Energy					
Energy is often transmitted in the form of waves.					
If a fine wire bristle is attached to the end of a tuning fork with a tiny drop of solder, what happens when the tuning fork is struck and a piece of smoked glass is placed beneath the wire bristle?		X			1
Matter may be transformed into energy and energy into matter, the sum-total, matter plus energy, remains constant.					
If a piece of coal is sealed into a jar with oxygen, the jar is weighed, and the coal is set on fire by an electric spark, what is the weight of the jar after burning is complete? How does the second weight compare with the first?		X			1
Mechanics					
There is a force called gravity which exerts a pull between any two objects no matter what their size nor where they are.					
If a coiled spring is attached to a solid support and hung in a vertical position, is there a difference in pull when objects of different size and weight are suspended from the free end of the spring?			X		1

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
The pressure under water becomes greater as the depth becomes greater.					
If the top of a thistle tube is covered with a sheet of rubber and the stem of the thistle tube is connected to a manometer by a rubber tube, what happens as the thistle tube is placed at various depths of water in a jar.	X				1
If a bottle is fitted with three jets placed at different heights along its side, which stream is projected outward the greatest distance when the bottle is filled with water?	X				1
A body emersed or floating in a liquid is buoyed up by a force equal to the weight of the fluid displaced.					
If a piece of aluminum foil is folded to make a "boat", what happens when it is placed on the surface of water in a jar? If the piece of aluminum foil is rolled into a ball, what happens when it is set on the surface of water?		X			1
If a stone is suspended from a spring scale, what happens to the weight registered on the scale, if, after the weight has been taken, the stone is lowered into a pail of water?			X		1
If a previously weighed pan is floated in a bucket filled to the brim with water so that the water displaced by the floating					

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
pan overflows the bucket into another pan, how does the weight of the amount of water which overflowed compare with the original weight of the floating pan? If stones are added to the floating pan until it is in danger of sinking, how does the weight of the displaced water compare with the weight of the floating pan plus its cargo?			X		1
If a known weight is suspended from a spring balance and lowered into a jar filled with water, how does the weight of the displaced water compare with the weight lost after the known weight was lowered into the water?		X	X		2
The pressure at a point in any fluid is the same in all directions.					
If the top of a thistle tube is covered with a sheet of rubber and the thistle tube is connected to a manometer by a rubber tube, and the thistle tube is placed below the surface of water in a jar, is there any change in the readings of the manometer as the thistle tube is turned in different directions at the same depth of water?	X				1
When the resultant of all the forces acting on a body is zero, the body will stay at rest, if at rest, or it will keep in uniform motion in a straight line, if it is in motion.					

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
If some books are placed on a piece of paper, what happens to the books when the paper is jerked from under them quickly?			X		1
If a marble is pushed by a pencil fairly rapidly over the top of a table, what happens when the pencil is brought to a sudden stop?			X		1
A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.					
If a gyroscope is caused to spin, what happens when you attempt to turn it?		X			1
Sliding friction is dependent upon the nature and condition of the rubbing surfaces.					
If a heavy book or box is pushed over the top of a table, does it drag? Is there a difference in drag if the book or box is rolled on four marbles?			X		1
In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.					
If a fulcrum is placed one foot from one end of a six foot lever, what force is required to balance a five pound weight placed on the end which is one foot from the fulcrum?				X	1

TABLE II (CONTINUED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.					
If one end of a smooth board four feet long is raised one foot, what force is necessary to pull a toy cart weighing one pound up the inclined plane? If the slope and weight of the cart are changed, what force is now needed to pull the cart up the inclined plane?			X		1
If one end of a plank 18 feet long is raised two feet higher than the other end, what force is required to pull a nine pound weight up the inclined plane? If one end of the plank is now raised six feet higher than the other end, what force is required to pull a three pound weight up the inclined plane?				X	1
The total mass of a quantity of matter is not altered by any chemical changes occurring among the materials composing it.					
If a piece of coal is sealed in a jar with oxygen, the jar is weighed, and the coal is set on fire by an electric spark, what is the weight of the jar after burning is complete? How does the second weight compare with the first?		X			1

TABLE II (CONCLUDED)

Principles and Experiments	Books in Which Experiments Occurred				
	M	S	P	D	T
Biology					
Osmosis, the diffusion of molecules of a solvent (usually water) through a semi-permeable membrane (a layer of cells or the membrane of a single cell) from the point of highest concentration of the solvent to a point of lower concentration, with a stoppage of the flow of molecules of the solute, is a basic process in plant and animal physiology.					
If the mouths of two thistle tubes are each covered with a piece of casing from a sausage and are suspended in an inverted position after a solution of sugar has been poured into one tube and plain water has been poured into the other, what happens when the thistle tubes are each lowered the same amount into a jar of water and allowed to stand?	X	X			2
The forms of all chlorophyll-bearing plants are adapted for carrying on photosynthesis.					
If parts of two or three leaves of a geranium plant are covered by pinning squares of cork and carbon paper on both sides and the plant is left in the sunlight for several hours, how do the covered parts of the leaves compare with the uncovered parts when they are all given the test for starch?		X		X	2

Findings. The total number of different assignments of experiments defensibly assigned to principles was 63. Of these, 61, or 96.8 percent, were assigned to principles of physical science, and 2, or 3.2 percent, were assigned to biological principles. The average number of experiments per book which were deemed suitable for developing understandings of principles was for physical science, 20.3; for biological science, 1.0 for both, 21.3. The number of experiments which were deemed suitable for developing understandings of principles of physical science varied from 14 to 26 for the four books. Comparable data showed only one such biological experiment for each of two books, two for one book, and none for the fourth book.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Restatement of the Problem

This investigation is made (1) to determine the principles and experiments of physical and biological science found in four ninth-grade textbooks of general science; and (2) to assign to these principles the experiments, the performance of which should help pupils of the ninth grade develop an understanding of the principles.

Summary of the Techniques Employed

This investigation was conducted after selecting four general science textbooks which conformed to criteria established by the investigator.

Criteria for the selection of principles from the textbooks were approved by a group of science teachers in a Seminar in Science Education, Boston University, 1946-47 and were adhered to in selecting the principles from the four textbooks analyzed.

Criteria for the statement of a principle for comprehension at the ninth-grade level were adopted by the same group. Every statement of a principle which complied with the criteria was selected from the textbooks.

The list of physical-science and biological-science

principles was reviewed by a specialist in the teaching of science who checked each principle for conformability to the criteria established for the statement of a principle for comprehension at the ninth-grade level and also for correct assignment to the related major principle or principles in Wise's or Martin's list. All statements of principles judged by the specialist as not conforming to the criteria and which he could not reword so as to conform were deleted from the final list of principles. Furthermore, if the language in a statement of a principle was not suitable for the ninth-grade level of comprehension, the specialist reworded the principle to make it comprehensible at that grade level.

All principles judged by the specialist to be incorrectly assigned by the investigator to the related major principle or principles in Wise's or Martin's list was so assigned by him to the related major principle or principles. Thus, the statement of the principles of science for comprehension at the ninth-grade level and their assignments to the related major principles in Wise's or Martin's list were validated.

An "index of the reliability" of the investigator's judgment in the selection of statements of principles from the four textbooks was determined by a reanalysis of a random sampling of 100 pages from one of the textbooks analyzed, two months after the first analysis. The "index of reliability" was 95.2 percent. This

indicated that the reliability of the investigator's judgment was sufficiently high.

A criterion for the selection of experiments from textbooks, which was adopted by the same Seminar, was adhered to in the selection of experiments from the four textbooks analyzed. The statements of the purposes of the experiments were written in question form.

The experiments were reviewed by a specialist in the teaching of science who checked each experiment for its conformability to the established criterion and also for its correct assignment to the major or minor principles of science found in the four textbooks. Any experiment judged by the specialist as not conforming to the criterion or which could not be reworded by him so as to conform was deleted from the final list of experiments.

Any experiments judged by the specialist not to be correctly assigned to principles were so assigned by him to the proper principles. Thus, the statements of the purposes of the experiments and their proper assignment to the major and minor principles found in the four textbooks were validated.

The "index of the reliability" of the investigator's judgment in the selection of experiments from the four textbooks was determined by a reanalysis of a random sampling of 100 pages from one of the textbooks analyzed, one month after the first analysis. The "index of the reliability" was 100 percent. Thus, the reliability of

the investigator's judgment in the selection of experiments from the textbooks was sufficiently high.

Summary of the Findings

The authors dwelt more on principles of physical science than on those of biological science. The principles of physical science outnumbered the principles of biological science by more than two to one. There was a definite lack of the use of principles of biological science. In very few instances was a particular principle repeated in the same textbook.

Conclusions

This investigation reveals that some authors of present day textbooks of general science still attempt to teach factual matter without showing its relationship to principles of science. Thus, there is shown a lack of recognition of the proven value of teaching principles of science. Moreover, some authors seem unable to delineate between principles, mere facts, and definitions. Furthermore, the textbooks seem to be written with a scope for use in any section of the country rather than being adapted to certain specific regions.

Recommendations

This investigation, which was the first of its kind to make use of defensible lists of principles of physical

science and biological science at the ninth-grade level of general education, has been responsible for the analysis of four ninth-grade textbooks of general science. There are several other general science textbooks written specifically for the ninth-grade level. It is, therefore, here recommended that the remaining ninth-grade general science textbooks be so analyzed. It is further recommended that the relative values of the various principles of science be determined for their inclusion in courses of study in general science at the ninth-grade level. It is also recommended that the relative values of the experiments suitable for the ninth grade be determined for their development of understandings of the principles of science. Moreover, suitable applications of these principles should be determined for courses of general science.

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APPENDIX

LIST OF EXPERIMENTS WHICH THE INVESTIGATOR COULD NOT ASSIGN TO A PRINCIPLE

If rods of iron, copper, glass, and zinc are each pushed through a piece of asbestos so that all four rods touch at one end, what happens to pieces of tallow placed at the other ends of the rods when heat is supplied at the point where the rods touch each other? Which rod conducts heat most rapidly?

If tufts of absorbent cotton are wrapped around the bulbs of several thermometers, and the thermometers are each dipped into separate types of liquids, viz. kerosene, water, alcolol, carbona, and ether, what is the temperature reading of each thermometer?

If one end of a long piece of glass tubing is held in a flame until it melts and the end of the tube closes, what happens if air is blown through the tube?

If the ends of pieces of wool, glass, stone, and metal are each placed against a hot surface, which heats up the quicker? Which takes the longer to heat up? If the pieces are now placed against a piece of ice, which cools the quicker? Which takes the longer to cool?

If three 250 cc. beakers, the first being wrapped in paper and covered with a board, the second being wrapped in aluminum foil and covered with metal, the third being left unwrapped and uncovered, are each placed in separate 400 cc. beakers of water and heated, what is the temperature of each after 10 minutes?

If a weighed piece of iron is heated and placed in a beaker of cold water and a beaker of boiling water equal in weight to the piece of iron is poured into a second beaker of cold water. which beaker will be the hottest after a stable temperature has been reached?

If a neon tube is attached to an induction coil, what happens when the coil is attached to a dry cell?

If two light bulbs are connected in series what happens when one bulb is unscrewed? What happens to the brightness when a third bulb is added? If the lights are now arranged in parallel, what happens when one bulb is unscrewed? What happens when a third bulb is added?

If a test tube containing a little water is stoppered loosely, what happens to the stopper as the water is heated to form steam?

What happens when steam generated in a flask is directed to the paddles of a paddle wheel?

If a test tube inverted in a beaker of water is placed under a bell jar, what happens to the water in the test tube as the air is pumped out of the bell jar? What happens as the air is allowed to flow back in?

If two deflated balloons - one tied, the other untied - are placed in a bell jar, what happens as the air is pumped out of the bell jar?

If two glass tubes connected at the top are placed, one in a beaker of water, the other in a beaker of oil, what happens when air is withdrawn from both tubes equally at the top?

If two bottles, one with water and stopper, the other open, are connected by a piece of bent tubing and placed in a bell jar, what happens when the air is pumped out of the jar?

If a spark plug, screwed into a hole in a tin can, is attached to an induction coil, which in turn is attached to two dry cells with a switch between, what happens when a few drops of ether are placed in the can, the cover is placed on the can, and the switch is thrown?

If a U-shaped glass tube is attached to a ruler and filled about one-third full of mercury, what is the difference in the level of mercury in the two arms when air is blown with the mouth into one end of the manometer tube? How many pounds per square inch does the reading correspond to?

If a darning egg with a nail driven into it is placed under a faucet with the large end up, how does the water flow over the darning egg? If a toy automobile is held under the faucet, how does the flow of water compare with the flow over the darning egg?

If a weight is tied to a support with a string, how does the rate of swing of the pendulum vary as the length of string is varied?

If a coin is placed on a card over the open mouth of a tumbler and the card is snapped with the finger what happens to the coin?

If a piece of paper is creased in the middle crosswise, folded, and one half of the paper is curved to make it convex, while the flat half is placed inside a book, what happens when you blow on the folded edge of the paper?

If a tablespoonful of alcohol is poured into a flask to which a stopper with a glass tube has been attached, and heated, what happens inside the flask when enough air has been pumped in to blow the stopper out?

If a box standing on end is fitted with a weight suspended from the top and a pencil is attached to the weight so that it just touches a piece of paper fastened to the bottom of the box, what happens when the box is jarred suddenly?

If a flask, fitted with a thistle tube and bent glass tubing which leads to an inverted bottle filled with water and standing in a water bath, is partly filled with a solution of molasses, warm water, and yeast, what happens to the water in the inverted bottle? What happens to a glowing splint when it is thrust into the bottle of collected gas?

If a solution of molasses and yeast is distilled using a distilling condenser, what is the nature of the liquid which collects from the end of the condenser?

If similar amounts of dough are placed in two separate jars, one with yeast, the other without, what occurs if the dough is allowed to stand overnight?

If a spoonful of sugar is heated in a dry test tube, what collects in the upper part of the tube? What happens to the sugar?

If two dry cells are connected in series and the loose ends of the wires are each placed under separate bottles which have been previously filled with water and inverted in a water bath, what happens to the water in the two bottles? Which bottle collects the gas more quickly? What happens when a lighted splinter is inserted into the bottle with the more abundant gas? What happens when a glowing splinter is inserted into the second bottle?

If a quarter of a teaspoonful of pure potassium chlorate is heated in a test tube, what happens when a glowing splinter is thrust into the test tube?

What happens when a tiny piece of metallic sodium is placed in a beaker of water? If the water is now evaporated in an evaporating dish what remains after all the water has been evaporated off?

If a small strip of magnesium ribbon is held in a pair of forceps, lighted with a match, what happens?

If five test tubes arranged in a rack are partly filled with dilute hydrochloric acid and pieces of magnesium, zinc, iron, tin, and copper are placed into separate tubes, which metal shows the most violent chemical activity? Which metal shows the least violent chemical activity?

If some steel wool is placed in a test tube and the tube is inverted over a beaker of water, what can be observed if the apparatus is allowed to stand overnight?

If a piece of pure iron is placed in one test tube and a piece of steel is placed in a second and the two metals are each covered with dilute nitric acid, what happens to the two pieces of metal? What remains in the test tube which contained the steel? the pure iron?

If equal parts of copper oxide and finely powdered charcoal are placed in a test tube and heated, what is the appearance of the material after it has been cooled and spread out on a piece of white paper?

If a carbon rod and a copper strip placed in a solution of copper sulfate are attached by wires to the terminals of a dry cell (the copper being attached to the central terminal), and left for a few minutes, what appears on the carbon rod?

If a sample of quicklime is placed in a beaker, what happens as water is added? If the slaked lime is mixed with sand and spread on a board what changes occur through a period of a few days?

If small pieces of soft coal are placed in a test tube and heated, what happens when the flame is applied to the gas escaping from the tube?

What happens to blue litmus paper after being placed in some fresh milk? If the milk is left in a warm place for forty-eight hours, what happens to blue litmus after being placed in this milk?

What happens to 16mm. film when a match is touched to it?

If a teaspoonful each of potassium chlorate and manganese dioxide is placed in a test tube, heated, and the gas given off is collected by the displacement of water, what happens when a glowing splint is thrust into

one of the bottles of gas? What happens when a piece of magnesium ribbon is burned in one of the bottles? What happens when sulfur in a deflagrating spoon is burned in one of the bottles? What happens when heated steel wool is thrust into one of the bottles?

If a piece of clay is moisened, kneaded, and pressed into a brick mold, what is its appearance after it has been heated under a can for a few hours? If cement, sand, and gravel are mixed with a little water and poured into a form, what is the appearance of the material after a day or two?

If the salts of copper, sodium, potassium, and cobalt are each held in a flame by a piece of iron wire, what colors are given off by each salt?

If the end of a parsnip root is cut off and the parsnip is stood on end for a few days in a glass of red ink, what can be observed?

If two geranium plants are each set under separate bell jars, one plant sitting in limewater and the other resting in plain water, what happens to the limewater? To the plain water? What gas is given off?

If two jars are filled with water and connected with a piece of bent glass tubing also filled with water except for an air bubble, and a leaf is inserted into one of the bottles so that its stem protrudes into the water, in which direction does the air bubble move when the apparatus is placed in sunlight?

If five sterilized Petri dishes are partly filled with agar and covered and sealed, after dish 1 has been uncovered for five minutes, dish 2 has been soiled with a small quantity of earth, dish 3 has had finger prints and a human hair placed in it, dish 4 has had a drop of water and a piece of meat placed in it, while dish 5 has been sealed immediately, what is observed at the end of 48 hours?

If a funnel is inverted in a jar of water, some seaweed is placed under the funnel, and a test tube filled with water is inverted over the funnel, what happens when the apparatus is placed in the sunlight? What happens when a glowing splint is thrust into the test tube of gas previously collected?

If a bottle containing peas wrapped in moist cotton is connected to a second bottle containing limewater by

means of bent glass tubing, what happens to the limewater as plain water is poured into the first bottle forcing the gas into the second bottle?

If a chicken bone is placed in dilute hydrochloric, left until it has softened, and the solution is heated in an evaporation dish, what appears in the dish after all the liquid has been evaporated away?

What happens to the pulse beat after doing a "standing run" for fifty paces? What happens to the pulse beat after being seated for ten minutes following the "standing run"?

If a toothpick with a drop of weak vinegar on the end is touched to the top of the tongue well toward the back of the mouth, is the vinegar tasted immediately? If the toothpick is touched to the side of the mouth, how quickly is the vinegar tasted?

If a thin paste of flour and water is heated, what happens when you add iodine solution? If thin corn syrup and Fehling's solution are heated in a test tube, what color appears? If a sixth of a test tube of nitric acid is added to a small amount of egg white or milk in a test tube and brought to a boil, what happens after the acid is carefully poured off and ammonium hydroxide is added? If a small amount of ground corn is placed on a piece of paper and heated over a metal disk, what appears on the paper around the corn?

If a little milk is gently heated in a test tube, what happens when a quarter teaspoonful of liquid rennet is added and the mixture is allowed to stand a few minutes? If dilute hydrochloric acid or vinegar is added to some milk in a test tube, what is the appearance after the mixture has been shaken?

If pieces of bronze, copper, and tin are each scratched with a steel knife, which scratches the least easily? Which scratches the easiest?

If pieces of marble and granite are each scratched with the point of a steel knife, which scratches more easily? Which scratches the harder?

If pieces of marble or limestone are placed in one bottle and pieces of granite are placed in another and water and hydrochloric acid are added, what happens in each bottle?

What happens if a test tube is filled with a mixture of soil and water and allowed to stand? If a test tube

is filled with a mixture of soil and water, what happens if the mixture is filtered through filter paper? If a lump of alum dissolved in some hot water is added to a test tube of soil and water, what happens when limewater is added and the solution is shaken? What sort of odor and taste will result from bubbling chlorine gas into tap water? If some pond water is examined under a microscope before and after chlorine gas has been bubbled into it, how do the two examinations compare?

If two persons stand facing each other at a distance of about two feet, what happens when one person drops a coin from a height of 30 inches and the second person tries to thrust his foot under it?

If samples of sand, clay, and humus are placed in separate lamp chimneys fitted with cloth at the base, what happens when the chimneys are placed in a pan of water? Which absorbs the water fastest? Which absorbs the most water?

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